Cracking

Claire Floyd
PhD. Student
ashlyn.floyd@uga.edu

Beni Rodriguez
Undergraduate Researcher
beni.rodriguez@uga.edu

Dr. Beshoy Morkos
bmorkos@uga.edu

Dr. Benjamin Wagner
wagner@uga.edu

UNIVERSITY OF GEORGIA
College of Engineering
Manufacturing Living Labs

USDA
FORT VALLEY STATE UNIVERSITY
I LOVE pecans
NPSA NATIONAL PECAN SHELLERS ASSOCIATION

Agenda

1. JC Half-Yield Optimization (Summer 2025)
2. JC Half-Yield Pecan Age
3. JC Half-Yield Verification
4. Meyer Half-Yield Optimization (Fall 2025)
5. Publication Status

2025 Recommendations

Recommendations	What we did
Verify and quantify 2025 maximized Half-Yield using recommended parameters.	Ran experiments for **pecan age comparison** and compared our **predicted results** from 2025 to **experimental values.**
Determine optimized Half-Yield for the Meyer Cracker.	Developed a model for determining **recommended parameters** to maximize Half-Yield.

JC Half-Yield Optimization

Summer 2025

UNIVERSITY OF GEORGIA

Motivation

- Efficient optimization of the cracking process will **significantly** impact the pecan post-harvesting process.
- Implement advanced technologies to provide **smarter machines** and **fine-tune cracking processes** to control pecan Half-Yields and to promote overall effectiveness.
- **Recommendations** to have a greater Half-Yield following the cracking process.

Recap from 2025 Workshop

2025 slides available: https://pecanresearch.uga.edu/

General trends are the SAME

Parameters	2025 Avg. Range Recommended for Max Half-Yield	2026 Avg. Range Recommended for Max Half-Yield (UPDATED)	Unit
Mid-Run Kernel Moisture	8-9	8-9	%
Mid –Run Shell Moisture	22-23	22-23	%
Plate Contact Frequency	50-55	50-55	Hz
Input Feed Rate	20-25	20-30	pecans/sec
Pecan Diameter	1.015 - 1.025	1.015-1.025	avg. in
Crush Amount	0.03-0.045	0.07-0.18	in
Entry-Exit Height Difference	-0.10 – -0.08	-0.10 - -0.08	in

Publication: Planned for Journal of Applied Food Research

Used for Multi-Stage

Recap from 2025 Workshop

2025 slides available:
https://pecanresearch.uga.edu/

General trends are the SAME

Parameters	2025 Avg. Range Recommended for Max Half-Yield	2026 Avg. Range Recommended for Max Half-Yield (UPDATED)	Unit
Mid-Run Kernel Moisture	8-9	8-9	%
Mid –Run Shell Moisture	22-23	22-23	%
Plate Contact Frequency	50-55	50-55	Hz
Input Feed Rate	20-25	20-30	pecans/sec
Pecan Diameter	1.015 - 1.025	1.015-1.025	avg. in
Crush Amount	0.03-0.045	0.07-0.18	in
Entry-Exit Height Difference	-0.10 – -0.08	-0.10 - -0.08	in

Publication: Planned for Journal of Applied Food Research

Used for Multi-Stage

JC Half-Yield: Pecan Age

Spring 2026

UNIVERSITY OF GEORGIA

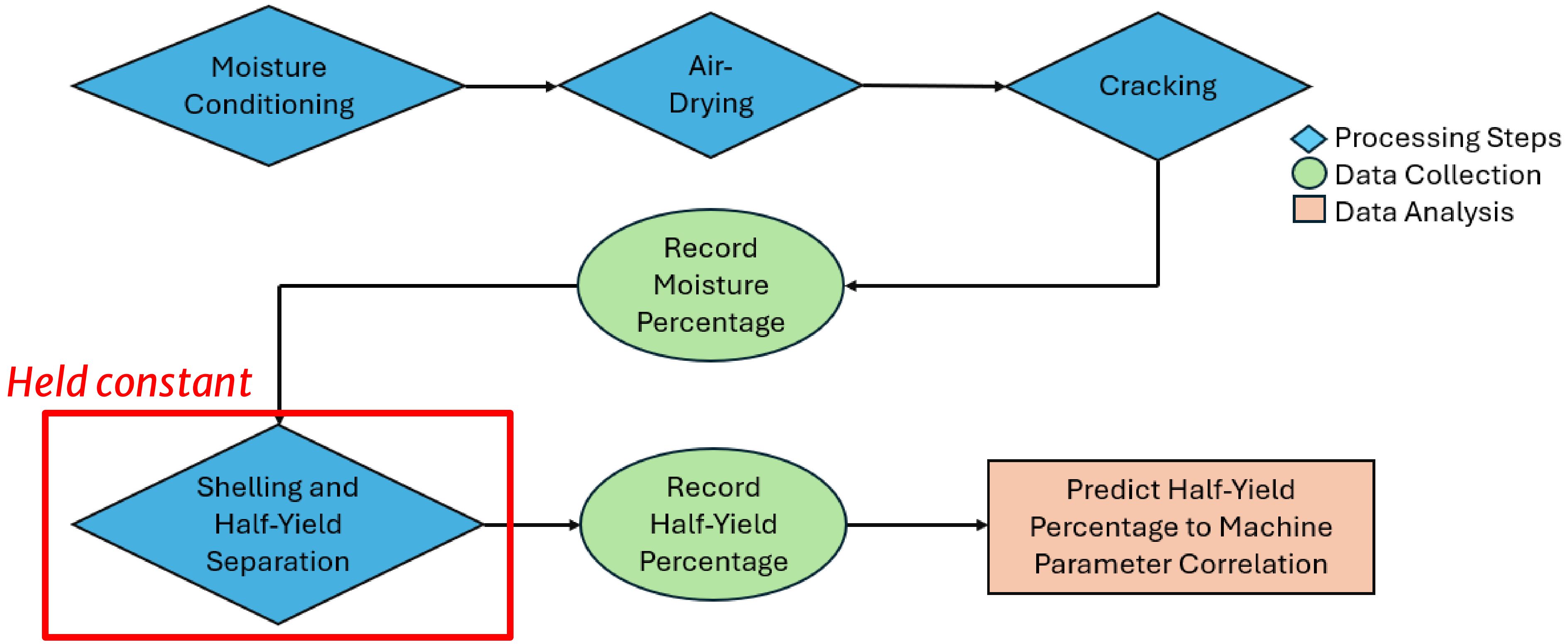
Assumptions

- **Disclaimer:** We are doing this in a controlled lab environment. The **trends** we present are valid, but the **absolute numbers** you see at your facility will likely **differ**.

- Results are based on our environment, pecan variety, and machine parameters.

- **All sheller settings remain constant throughout our testing.**
  - Listed in the following tables
  - Pin material: Standard Steel Gradient

Experimental Procedure



Cracking Parameters

- **Plate Contact Frequency:** Vibratory frequency of the plate impacting pecans (Hz).
- **Input Feed Rate:** Number of pecans entering the JC per second (**pecans/sec**).
- **Crush Amount:** Change in height to crack the pecans, impact for the 0 setting plus/minus the given value (**in**).
- **Entry/Exit Height Difference:** Vertical change between the opening and exit of the JC due to tilt of the crush plate (**in**).
- **Moisture Content:** Kernel moisture percentage changed by varying soaking times (**%**).

Cracking Parameters

- **Plate Contact Frequency:** Vibratory frequency of the plate impacting pecans (**Hz**).
- **Input Feed Rate:** Number of pecans entering the JC per second (**pecans/sec**).
- **Crush Amount:** Change in height to crack the pecans, impact for the 0 setting plus/minus the given value (**in**).
- **Entry/Exit Height Difference:** Vertical change between the opening and exit of the JC due to tilt of the crush plate (**in**).
- **Moisture Content:** Kernel moisture percentage changed by varying soaking times (**%**).

Cracking Parameters

- **Plate Contact Frequency:** Vibratory frequency of the plate impacting pecans (**Hz**).
- **Input Feed Rate:** Number of pecans entering the JC per second (**pecans/sec**).
- **Crush Amount:** Change in height to crack the pecans, impact for the 0 setting plus/minus the given value (**in**).
- **Entry/Exit Height Difference:** Vertical change between the opening and exit of the JC due to tilt of the crush plate (**in**).
- **Moisture Content:** Kernel moisture percentage changed by varying soaking times (**%**).

Cracking Parameters

- **Plate Contact Frequency:** Vibratory frequency of the plate impacting pecans (**Hz**).
- **Input Feed Rate:** Number of pecans entering the JC per second (**pecans/sec**).
- **Crush Amount:** Change in height to crack the pecans, impact for the 0 setting plus/minus the given value (**in**).
- **Entry/Exit Height Difference:** Vertical change between the opening and exit of the JC due to tilt of the crush plate (**in**).
- **Moisture Content:** Kernel moisture percentage changed by varying soaking times (**%**).

Cracking Parameters

- **Plate Contact Frequency:** Vibratory frequency of the plate impacting pecans (**Hz**).
- **Input Feed Rate:** Number of pecans entering the JC per second (**pecans/sec**).
- **Crush Amount:** Change in height to crack the pecans, impact for the 0 setting plus/minus the given value (**in**).
- **Entry/Exit Height Difference:** Vertical change between the opening and exit of the JC due to tilt of the crush plate (**in**).
- **Moisture Content:** Kernel moisture percentage changed by varying soaking times (**%**).

Half-Yield: Pecan Age

Motivation

- When beginning experiments after an extended time, the team saw very low (**~40-50%**) Half-Yield measurements.
- Our current measurements are usually **above 50%.**

Goal

- How does pecan age influence Half-Yield measurements?
  - Run a comparison between an **old batch** (over 3 weeks old) and a **new batch** (newly delivered).

Pecan Age Half-Yield Test

Old batch
New batch

Null Hypothesis for Old Batch
H_0: $\mu_{\text{Half-Yield}} > 50\%$
p-value = 0.0121

Run ID	Soaking Time (hr)	Air-Dry Time (min)	Input Feed Rate (pecan/sec)	Entry-Exit height (in)	Crush amount (in)	Plate Freq (Hz)	Ring gap (in)	Paddle (RPM)	Drum (RPM)	Mid-Run Kernel Moisture (%)	Half-Yield (%)
1	21:00:00	0:30:00	27.5	-0.09	0.15	52	0.45	600	30	9.06	44.15%
2	19:30:00	0:30:00	27.5	-0.09	0.15	52	0.45	600	30	8.92	40.95%
3	21:30:00	0:30:00	27.5	-0.09	0.15	52	0.45	600	30	6.82	48.90%
4	23:30:00	0:30:00	27.5	-0.09	0.15	52	0.45	600	30	7.26	41.58%
5	27:30:00	0:30:00	27.5	-0.09	0.15	52	0.45	600	30	8.28	47.15%
6	17:00:00	0:30:00	27.5	-0.09	0.15	52	0.45	600	30	7.68	64.10%
7	18:30:00	0:30:00	27.5	0.03	0.15	52	0.45	600	30	8.38	50.67%
8	23:00:00	0:15:00	27.5	-0.1	0.07	50	0.45	600	30	8.02	62.78%

Avg. 44.55%

Avg. 59.18%

Avg. ~15% ⇧

Pecan Age Conclusions

- Pecan age **significantly** influences Half-Yield.

Avg. 44.55%	Old batch of pecans
Avg. 59.18%	New batch of pecans
Avg. ~15% ⇧	Increase in half-yield

- **Main conclusion:** Pecans should be used in a **timely manner**, and refrigeration practices should be used to maintain pecan quality.
- **Potential future work:** Measuring appropriate pecan aging to **quantify** usable pecans in an ambient lab environment.

Pecan Age Conclusions

- Pecan age **significantly** influences Half-Yield.

Avg. 44.55%	Old batch of pecans
Avg. 59.18%	New batch of pecans
Avg. ~15% ⇧	Increase in half-yield

- **Main conclusion:** Pecans should be used in a **timely manner**, and refrigeration practices should be used to maintain pecan quality.
- **Potential future work:** Measuring appropriate pecan aging to **quantify** usable pecans in an ambient lab environment.

JC Half-Yield Verification

Spring 2026

UNIVERSITY OF GEORGIA

Half-Yield: Verification from 2025 Results

Motivation

- Verifying last year's results before Multi-Stage.

Goal

- Maximize Half-Yield based on 2025 results.
  - Compare experimental findings to the 2025 predictive results.

JC Optimized Range for Half Yields

2025 slides available: https://pecanresearch.uga.edu/

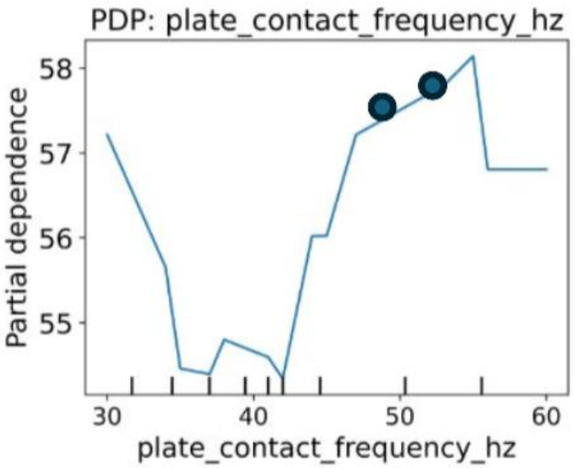
General trends are the SAME

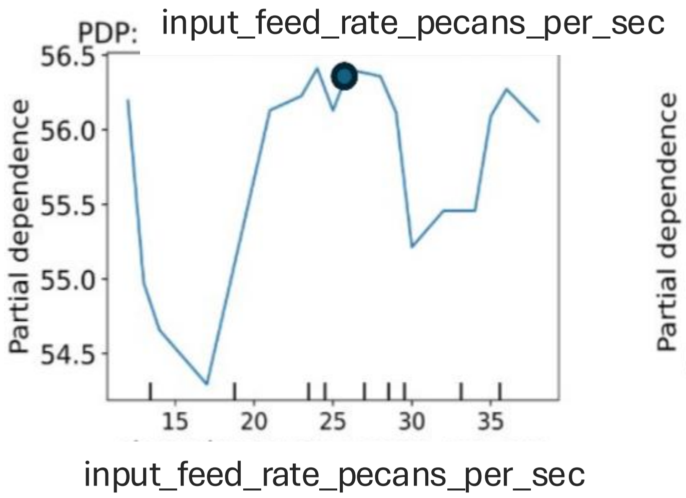
Parameters	2026 Average Range Recommended for Max Half-Yield	Unit
Mid-Run Kernel Moisture	8-9	%
Mid-Run Shell Moisture	22-23	%
Plate Contact Frequency	50-55	Hz
Input Feed Rate	20-30	pecans/sec
Pecan Diameter (Desirables)	1.015-1.025	avg. in
Crush Amount	0.07-0.18	in
Entry-Exit Height Difference	-0.10 - -0.08	in

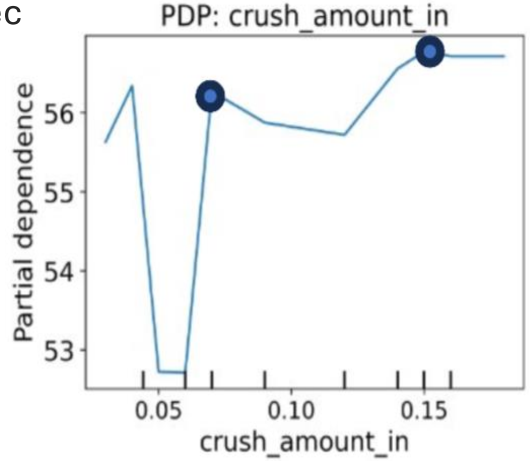
Publication: Planned for Journal of Applied Food Research

General trends are the SAME compared to 2025 results

Maximizing Half-Yield Results

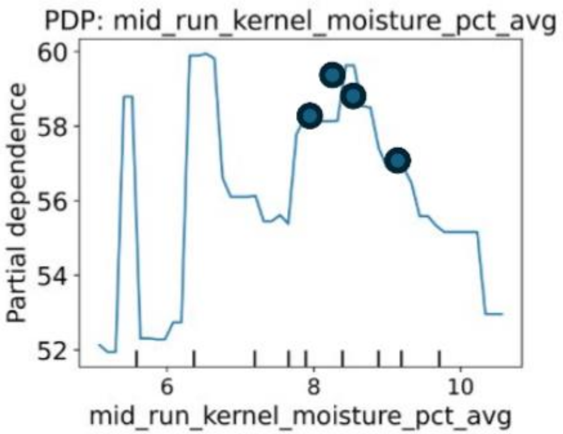


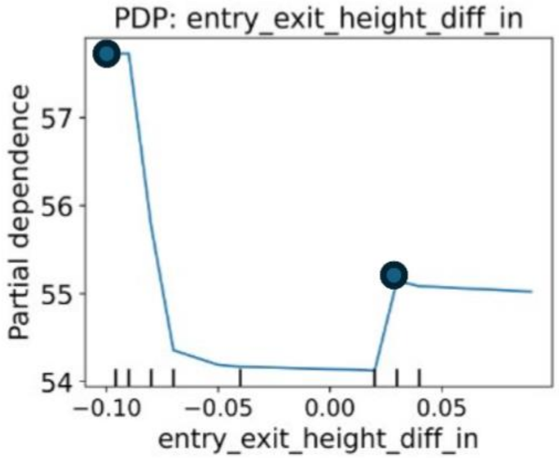




PDP: Partial Dependence Plot

PDP applies when all other features are held constant except one (the x-axis).





● Max Half-Yield

Maximizing Half-Yield Test

Within optimized range
Outside optimized range

Validating results from 2025

Run ID	Soaking Time (hr)	Air-Dry Time (min)	Input Feed Rate (pecan/sec)	Entry-Exit Height (in)	Crush Amount (in)	Plate Freq (Hz)	Ring Gap (in)	Paddle (RPM)	Drum (RPM)	Mid-run Kernel Moisture (%)	Half-Yield (%)
1	21:00:00	15	27.5	-0.1	0.07	50	0.45	400	30	8.88	58.97
2	22:15:00	19	27.5	-0.1	0.07	50	0.45	400	30	9.54	59.32
5	23:30:00	15	27.5	-0.09	0.15	50	0.45	400	30	9.10	61.88
7	26:00:00	15	27.5	0.03	0.15	52	0.45	400	30	8.08	76.85
8	27:15:00	15	27.5	0.03	0.15	52	0.45	400	30	8.00	74.03

Conclusions

- **General trends** from experimental testing **matched** 2025 predicted model results.
  - Experimental Half-Yield reached results **above predicted** Half-Yield.
  - Predicted values set a **threshold** for minimum Half-Yield.

- **Entry-Exit Height** was an **outlier** for this testing.
  - Potential Causes: natural pecan variation, lower sheller run speed, etc.

Meyer Half-Yield Optimization

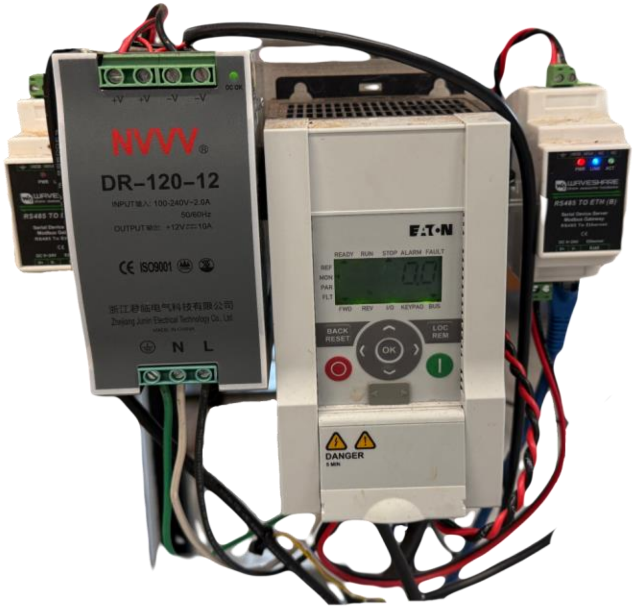
Fall 2025

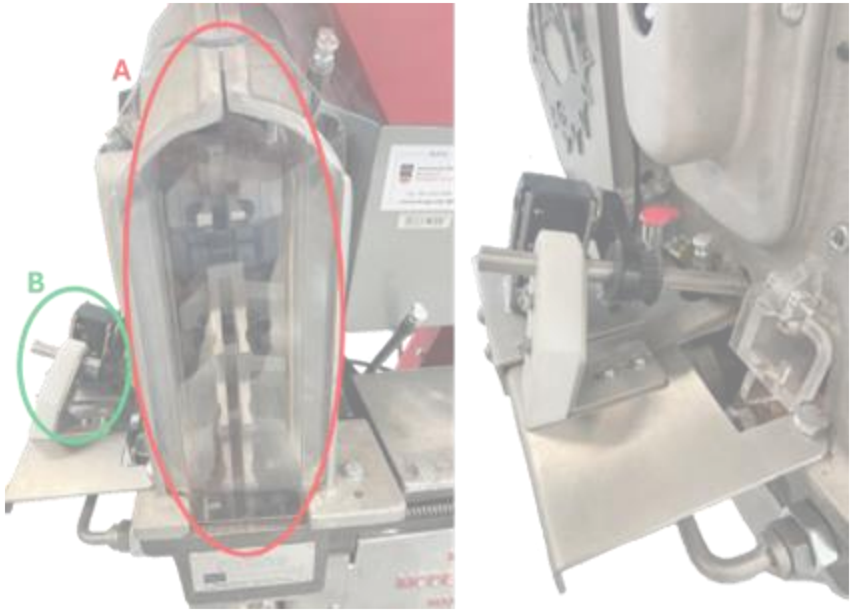
UNIVERSITY OF GEORGIA

Equipment

System Updates

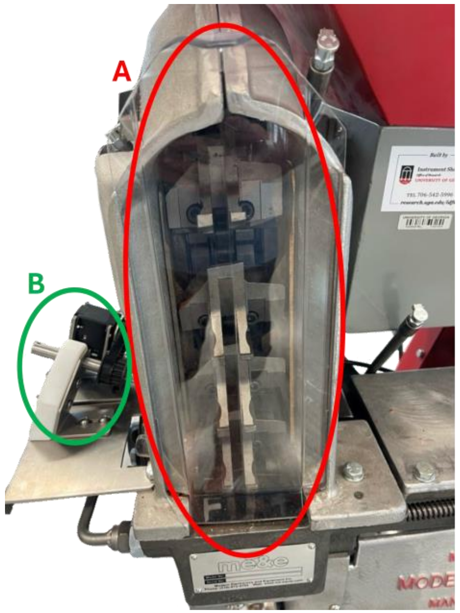
- **Digital platform** added to control machine parameters
- **Replaced single-phase motor** with **Variable Frequency Drive (VFD) three-phase motor**
- **Polycarbonate panel (A)** view of pecans moving through gear teeth
- **Set screw servo motor (B)** to change set screw displacement through digital platform





System Updates

- **Digital platform** added to control machine parameters
- **Replaced single-phase motor** with **Variable Frequency Drive (VFD) three-phase motor**
- **Polycarbonate panel (A)** view of pecans moving through gear teeth
- **Set screw servo motor (B)** to change set screw displacement through digital platform



Research Questions

(1) Which **machine parameters** explain **the greatest variation in Half-Yield** (%) when cracking pecans?

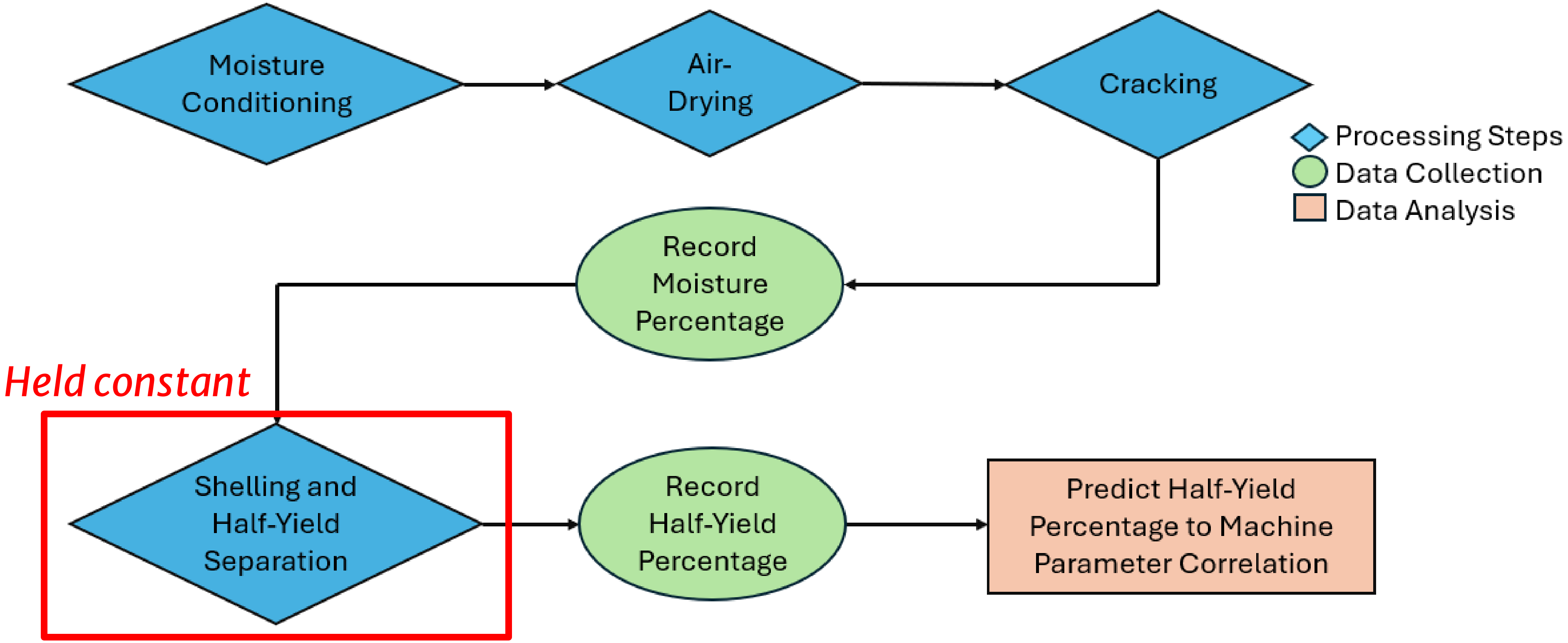
(2) Which combination of **machine parameters maximizes Half-Yield** (%) while satisfying pre-specified constraints on crack quality?

Assumptions

All sheller settings remain constant throughout our testing:

- **Drum Speed:** 30 RPM
- **Ring Gap:** 0.45-inch
- **Paddle Shaft Speed:** 600 RPM
- **Tilt Angle:** 2.5 degrees
- **Pin material:** Standard Steel Gradient

Experimental Procedure



Cracking Parameters

- **Set Screw Displacement:** Change in displacement of the screw contacting the die (**in**).
- **Preload Spring Stiffness:** Stiffness of inner contact spring (**N/m**).
- **Motor Speed:** VFD-driven motor increases the number of pecans cracked per minute based on increased frequency (**Hz**).
- **Moisture Content:** Kernel moisture percentage changed by varying soaking times (**%**).

Cracking Parameters

- **Set Screw Displacement:** Change in displacement of the screw contacting the die (**in**).
- **Preload Spring Stiffness:** Stiffness of inner contact spring (**N/m**).
- **Motor Speed:** VFD-driven motor increases the number of pecans cracked per minute based on increased frequency (**Hz**).
- **Moisture Content:** Kernel moisture percentage changed by varying soaking times (**%**).

Cracking Parameters

- **Set Screw Displacement:** Change in displacement of the screw contacting the die (**in**).
- **Preload Spring Stiffness:** Stiffness of inner contact spring (**N/m**).
- **Motor Speed:** VFD-driven motor increases the number of pecans cracked per minute based on increased frequency (**Hz**).
- **Moisture Content:** Kernel moisture percentage changed by varying soaking times (**%**).

Cracking Parameters

- **Set Screw Displacement:** Change in displacement of the screw contacting the die (**in**).
- **Preload Spring Stiffness:** Stiffness of inner contact spring (**N/m**).
- **Motor Speed:** VFD-driven motor increases the number of pecans cracked per minute based on increased frequency (**Hz**).
- **Moisture Content:** Kernel moisture percentage changed by varying soaking times (**%**).

DOE

Sample size for each run was 33 lbs.

Independent Variables	Variable Ranges			Unit
Set Screw Displacement	0.285-0.315			in
Preload Spring Stiffness	1800	2000	2200	N/m
Motor Speed	30-60			Hz
Moisture Content	5-10			%

Later referred to as *Phase 1*

DOE

Sample size for each run was 33 lbs.

Independent Variables	Variable Ranges			Unit
Set Screw Displacement	0.285-0.315			in
Preload Spring Stiffness	1800	2000	2200	N/m
Motor Speed	30-60			Hz
Moisture Content	5-10			%

Later referred to as *Phase 1*

DOE

Sample size for each run was 33 lbs.

Independent Variables	Variable Ranges			Unit
Set Screw Displacement	0.285-0.315			in
Preload Spring Stiffness	1800	2000	2200	N/m
Motor Speed	30-60			Hz
Moisture Content	5-10			%

DOE

Sample size for each run was 33 lbs.

Independent Variables	Variable Ranges			Unit
Set Screw Displacement	0.285-0.315			in
Preload Spring Stiffness	1800	2000	2200	N/m
Motor Speed	30-60			Hz
Moisture Content	5-10			%

Methodology

- With a full factorial, we would have been required to run 243 experiments.
- A strategic decision was made to use Latin Hypercube Sampling (LHS) and run a **40-experiment representative sample**.
- Based on the current capability of the machine, we tested a wide range of **variables.**
  - **Set Screw Displacement**
  - **Preload Spring Stiffness**
  - **Motor Speed**
  - **Moisture Content**

Saved ~1015 experimental hours
and ~6,699 lbs of pecans
= ~$41,331 in savings

NOTE: We would like to **acknowledge** that our analysis was verified by the UGA Statistics Department (Dr. Dan Hall, Dr. Abhyuday Mandal, Kyle Fuentes-Keuthan)

Data Structure

Independent Variables

Dependent Variables

Run Id	Motor Speed (Hz)	Set Screw Displacement (in)	Spring Stiffness (N/m)	Midrun Kernel Moisture (%)	Midrun Shell Moisture (%)	Final Half Kernel Yield (%)
1	33	-0.307	1800	6.86	23.74%	64.17%
2	30	-0.311	2000	9.56	24.62%	56.08%
3	47	-0.291	1800	6.62	25.00%	62.28%
4	42	-0.314	2000	5	21.25%	58.86%
5	53	-0.302	1800	8.52	24.21%	65.05%
6	37	-0.301	2200	6.8	24.31%	61.47%
7	40	-0.286	2000	5.18	20.98%	59.56%
8	39	-0.309	1800	7.28	24.27%	71.83%
9	49	-0.299	2200	5.16	20.45%	58.02%
10	47	-0.295	2000	8.02	39.93%	58.60%
11	52	-0.302	2000	9.24	12.62%	58.96%
12	59	-0.299	1800	9.5	25.34%	72.07%
13	41	-0.312	2000	5.56	22.83%	59.37%

Based on the tests guided by LHS, more tests on optimized variables were run for new data ranges.

Phase 2 DOE

Sample size for each run was 33 lbs.

Independent Variables	Variable Ranges			Unit
Set Screw Displacement	0.288-0.312			in
Preload Spring Stiffness	1800	2000	2200	N/m
Motor Speed	32-59			Hz
Moisture Content	5-10			%

Phase 2 DOE

Sample size for each run was 33 lbs.

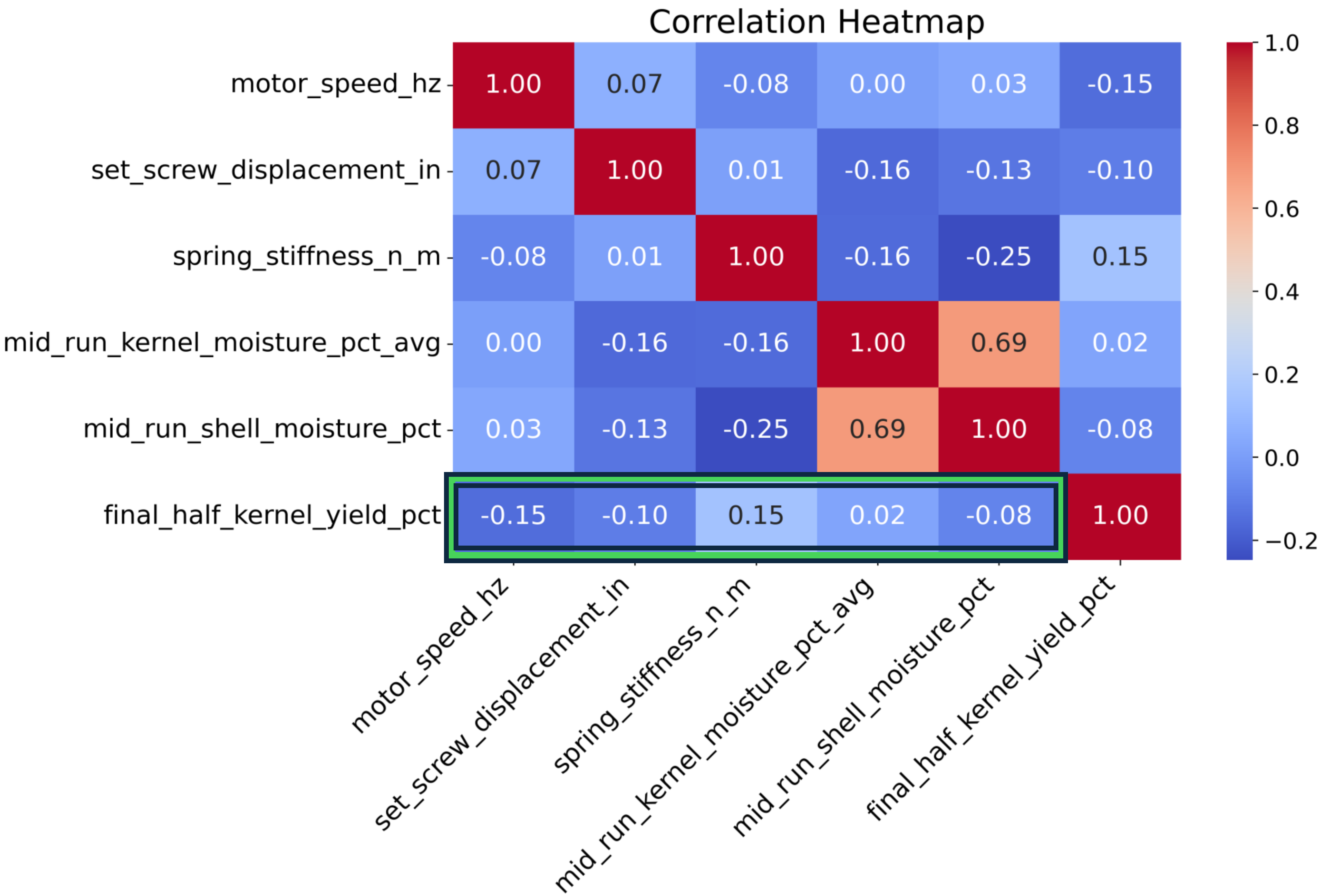
Independent Variables	Variable Ranges			Unit
Set Screw Displacement	0.288-0.312			in
Preload Spring Stiffness	1800	2000	2200	N/m
Motor Speed	32-59			Hz
Moisture Content	5-10			%

Research Questions

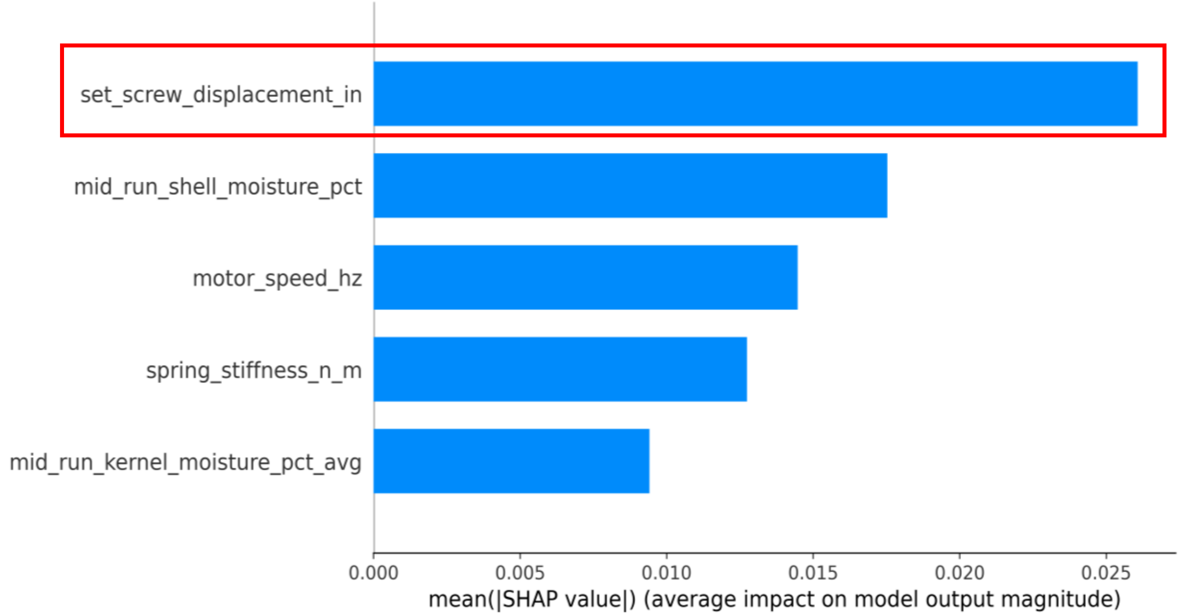
(1) Which **machine parameters** explain **the greatest variation in Half-Yield** (%) when cracking pecans?

Correlation

- Half-Yield is driven by the combined influence of multiple features rather than one dominant variable.

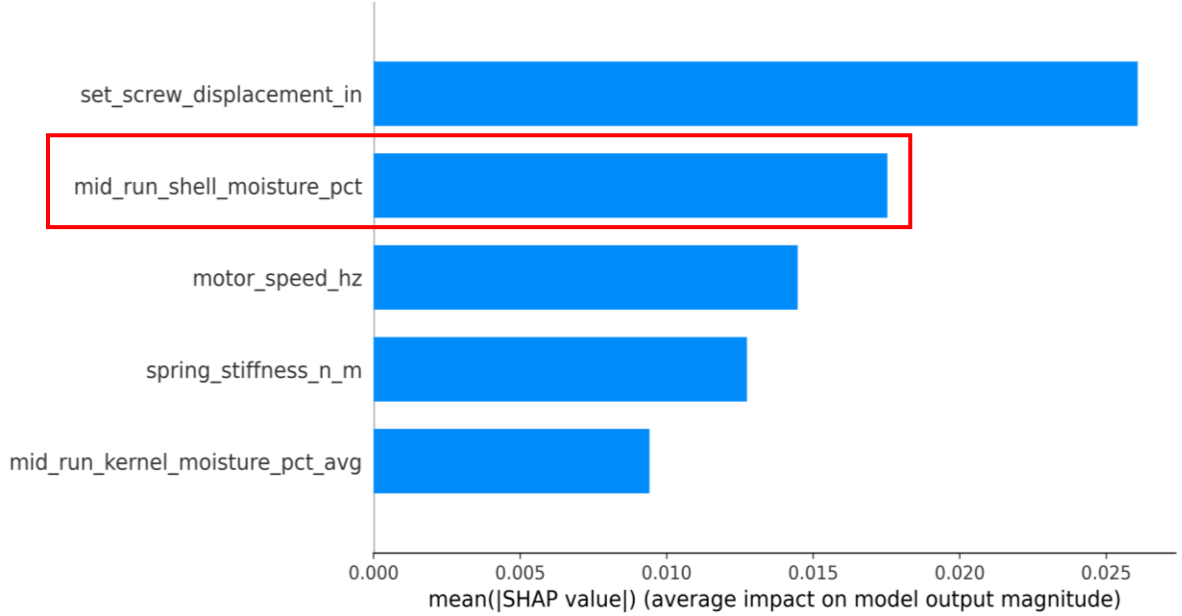


XGBoost with SHAP (SHapely Additive exPlanation) Interaction Analysis



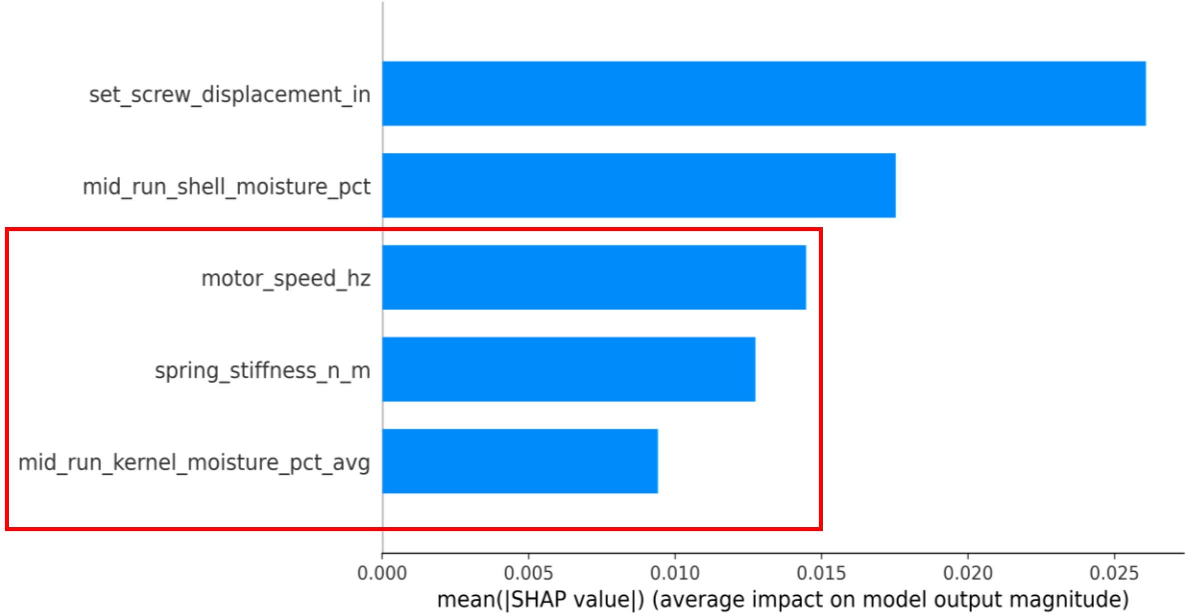
- **Set Screw Displacement ↓ Half-Yield ↑**
- **Shell Moisture ↓ Half-Yield ↑**
- **Motor Speed, Spring Stiffness, Kernel Moisture: minimal effect on Half-Yield.**

XGBoost with SHAP (SHapely Additive exPlanation) Interaction Analysis



- Set Screw Displacement ↓ Half-Yield ↑
- **Shell Moisture ↓ Half-Yield ↑**
- Motor Speed, Spring Stiffness, Kernel Moisture: minimal effect on Half-Yield.

XGBoost with SHAP (SHapely Additive exPlanation) Interaction Analysis



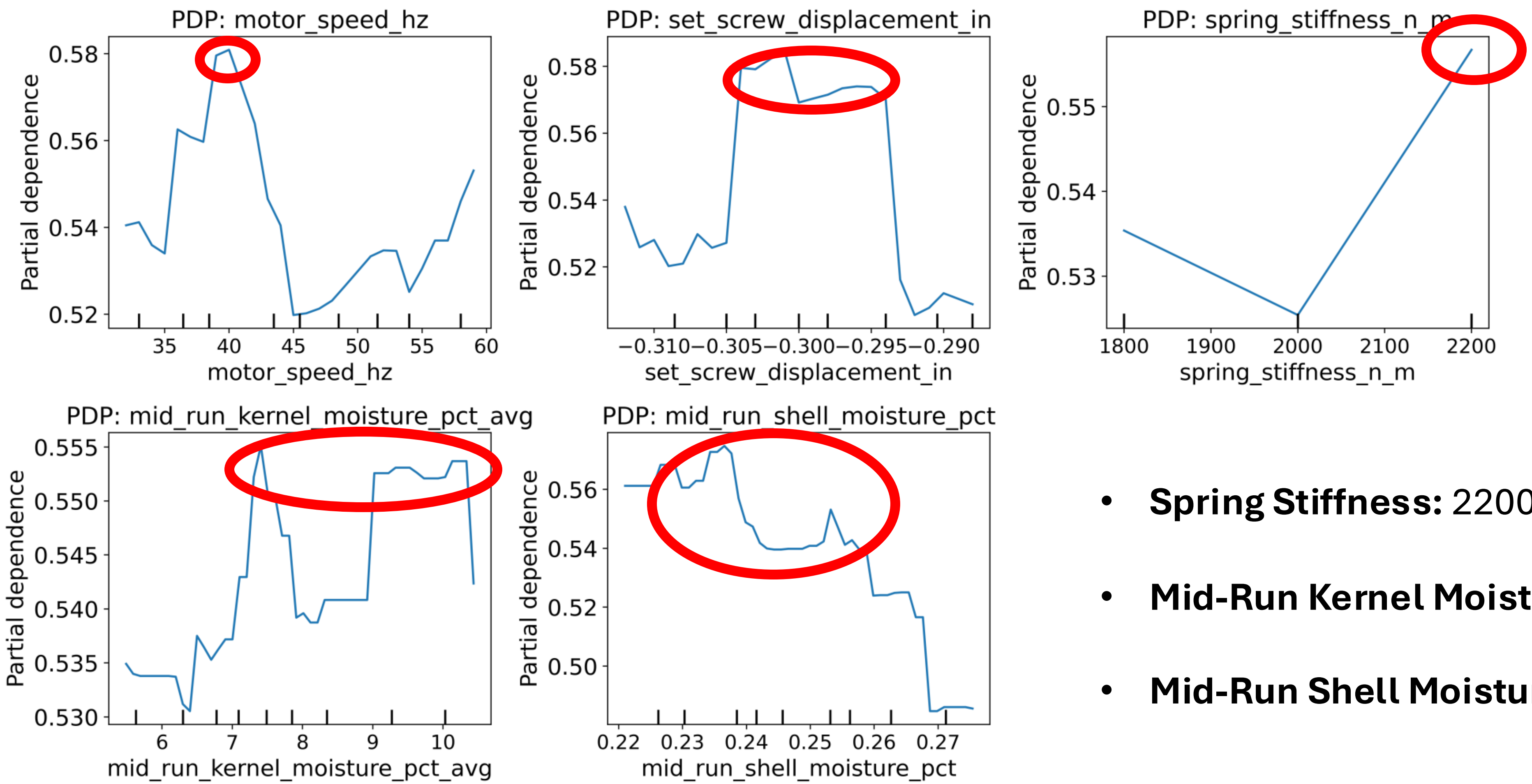
- Set Screw Displacement ↓ Half-Yield ↑
- Shell Moisture ↓ Half-Yield ↑
- **Motor Speed, Spring Stiffness, Kernel Moisture:** minimal effect on Half-Yield.

Research Questions

(2) Which combination of **machine parameters maximizes Half-Yield** (%) while satisfying pre-specified constraints on crack quality?

This applies when other features are kept constant except this one feature.

PDP (Partial Dependence Plots) Recommendations



- **Motor Speed:** 40 to 60 Hz
- **Set Screw Displacement:** -0.305 to -0.294 in

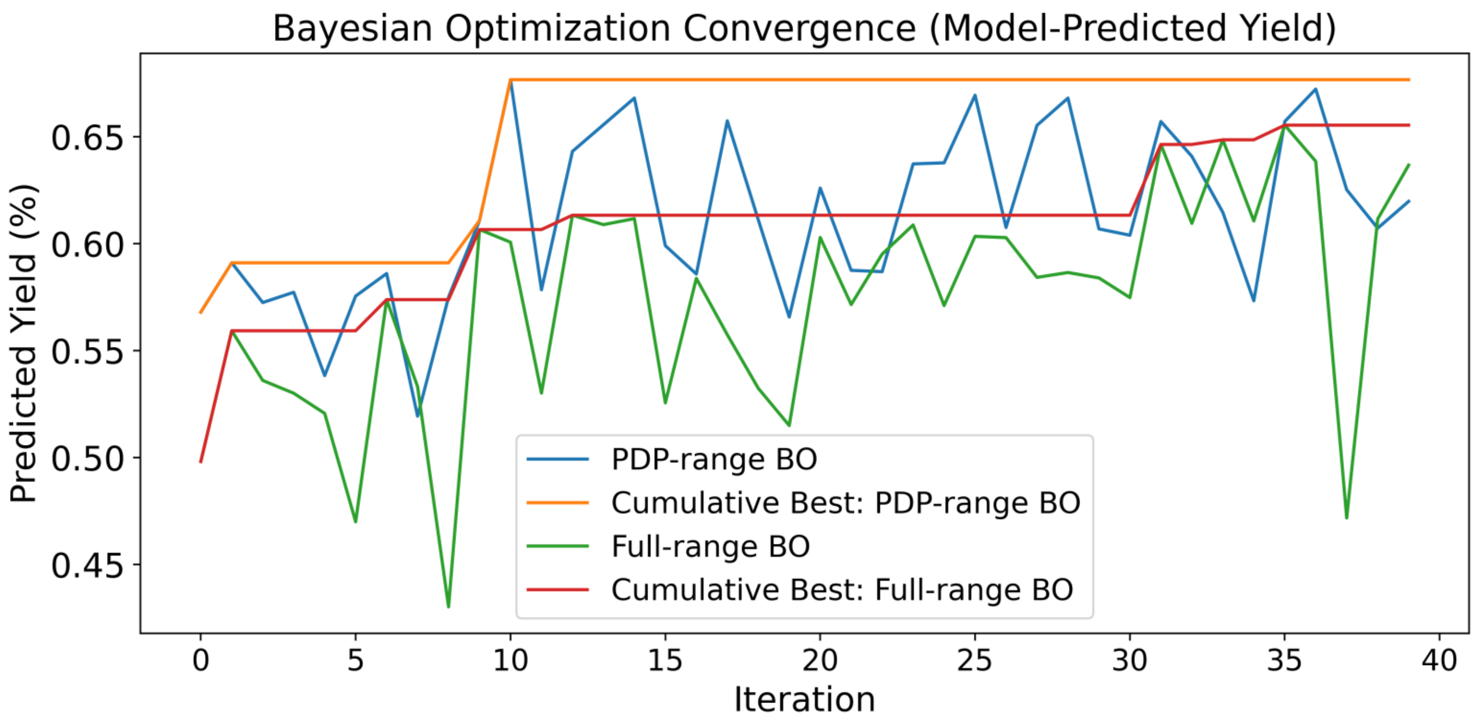
- **Spring Stiffness:** 2200 N/m
- **Mid-Run Kernel Moisture:** 7 to 10 %
- **Mid-Run Shell Moisture:** 23.5 to 25.5 %

Bayesian Optimization (BO)

- This approach also allows us to compare the predicted half yield from the **PDP-based ranges** against the predicted yield from the **Full data range**.

- PDP-range BO predicted **67.66% Yield.**

- Full-range BO predicted **65.54% Yield**

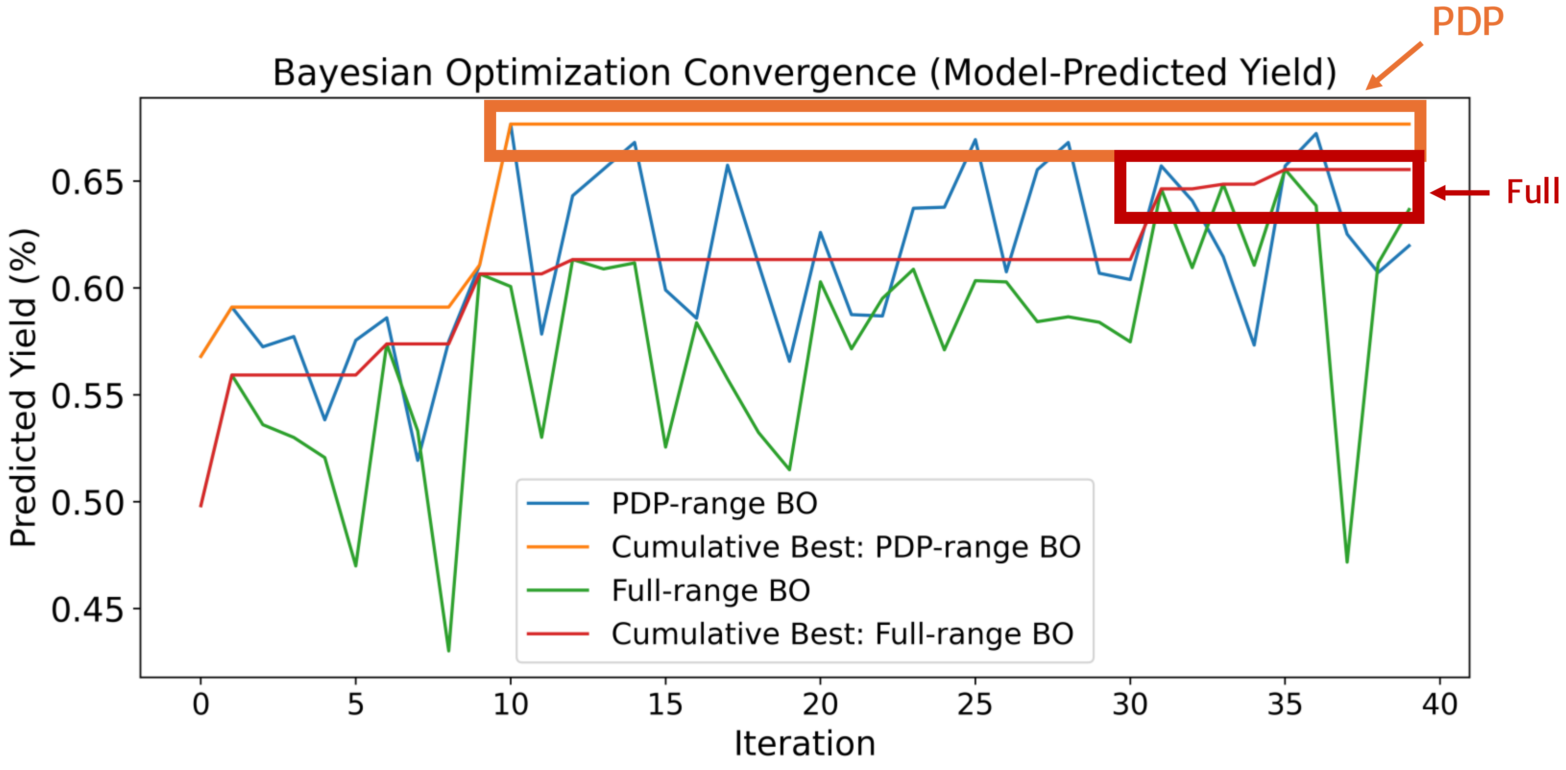


Bayesian Optimization (BO)

- This approach also allows us to compare the predicted half yield from the **PDP-based ranges** against the predicted yield from the **Full data range**.

- PDP-range BO predicted **67.66% Yield.**

- Full-range BO predicted **65.54% Yield**

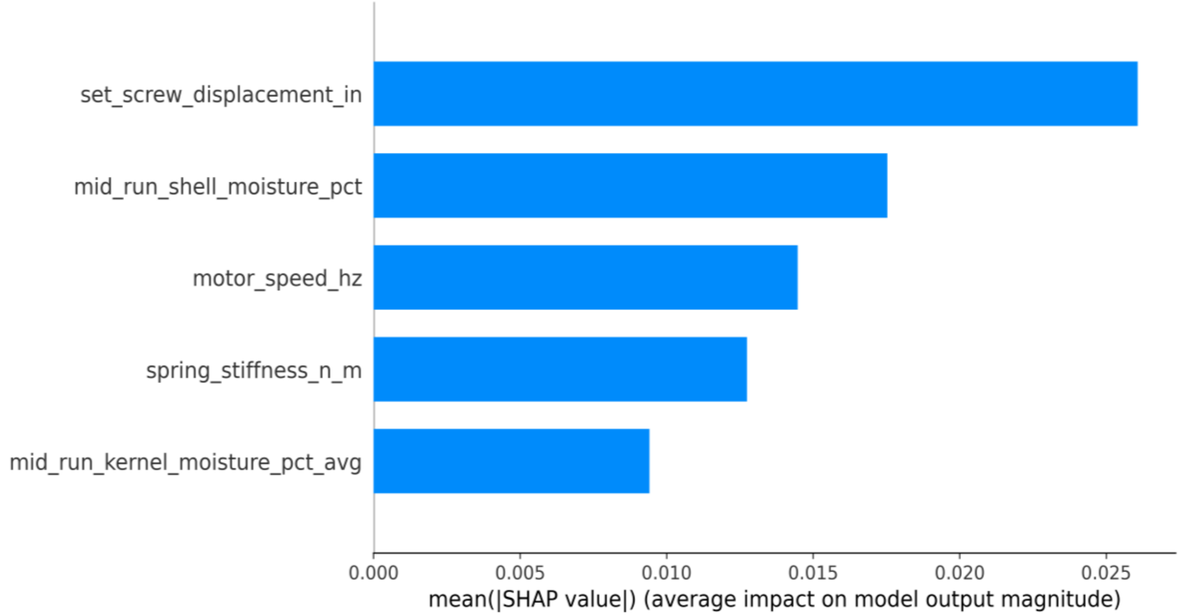


Bayesian Optimization (BO)

Same conclusion **verified** for PDP training compared to full dataset.

Bayesian Optimization			
Variable	**PDP Range**	**Full Range**	**Unit**
Motor Speed	60	58.03	Hz
Set Screw Displacement	-0.300	-0.300	in
Spring Stiffness	2200	2200	in
Kernel Moisture	7	6.70	%
Shell Moisture	23.5	20.06	%
Predicted Yield	67.66	65.54	%

XGBoost with SHAP (SHapely Additive exPlanation) Interaction Analysis



- **Set Screw Displacement ↓ Half-Yield ↑**
- **Shell Moisture ↓ Half-Yield ↑**
- **Motor Speed, Spring Stiffness, Kernel Moisture:** minimal effect on Half-Yield.

This applies when other features are kept constant except one feature.

Summary

Sheller Settings
- 30 RPM drum speed
- 0.45-inch ring gap
- 600 RPM paddle shaft speed
- 2.5-degree tilt angle

Parameters	Average Range Recommended for Max Half-Yield
Motor Speed	40 to 60 (Hz)
Set Screw Displacement	-0.305 to -0.294 (in)
Spring Stiffness	2200 (N/m)
Pecan Diameter (Desirables)	1.015 to 1.025 (in)
Kernel Moisture	7 to 10 (%)
Shell Moisture	23.5 to 25.5 (%)

Publication Status

Summer 2026

UNIVERSITY OF GEORGIA

Paper Overview

Paper #1: "*Comprehensive Characterization of an End-to-End Pecan Cracking System for Optimal Crack Quality Assessment*"
In review process – Journal of Applied Food Research

Paper #2: "*Optimizing Pecan Half-Yield Output in the Context of Axial and Radial Cracking Technology*"
In progress – planned submission to Journal of Applied Food Research (Fall 2026)

Paper Overview

Paper #1: "*Comprehensive Characterization of an End-to-End Pecan Cracking System for Optimal Crack Quality Assessment*"
In review process – Journal of Applied Food Research

Paper #2: "*Optimizing Pecan Half-Yield Output in the Context of Axial and Radial Cracking Technology*"
In progress – planned submission to Journal of Applied Food Research (Fall 2026)

Claire Floyd LinkedIn

Bruna Valiate LinkedIn

Beni Rodriguez LinkedIn

All slides available: https://pecanresearch.uga.edu/

Thank you!

Questions & Comments

Special thank you to Bruna Karoline Valiate (PhD Student) and Beni Rodriguez (Undergraduate Researcher).